Simulated HyspIRI Volcanology Data Sets

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Goals of Project

The primary objective of this proposal is to create precursor HyspIRI-like data sets to examine several important volcanological questions:

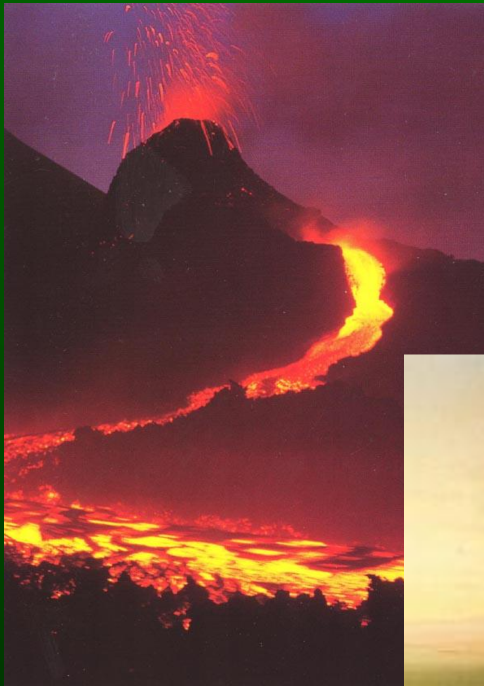
1 What do changes in SO_2 emissions tell us about a volcano's activity?

2 How do we use measurements of lava flow temperatures and volume to predict advances of the flow front?

3 What do changes in lava lake temperatures and energy emissions tell us about possible eruptive behavior?

A second objective is to determine the saturation temperature for the Mid-IR band

ETNA



Why Mt. Etna?

- Europe's most active volcano
- Explosive and effusive eruptions
- Massive SO_2 emitter
- Extraordinarily frequent remote sensing data acquisitions
- Very well monitored by INGV
- Co-I at INGV will provide all ancillary data needed

Characteristics of Input Data Sets

	EO-1 Hyperion	ASTER TIR
Bands	196 unique in 0.4-2.5 micron region	5 in 8-12 micron region
Spatial resolution	30 m	90 m
Swath	7.5 km	60 km
Quantization	16 bit	12 bit

Ancillary Data Sets

	COSPEC SO_2	Flow field Topography	Eruption chronology
Eruptions and gas emissions	X		X
Lava flow modeling		X	X
Lava lake energy release			X

ASTER Daytime Scenes (1 2 3)

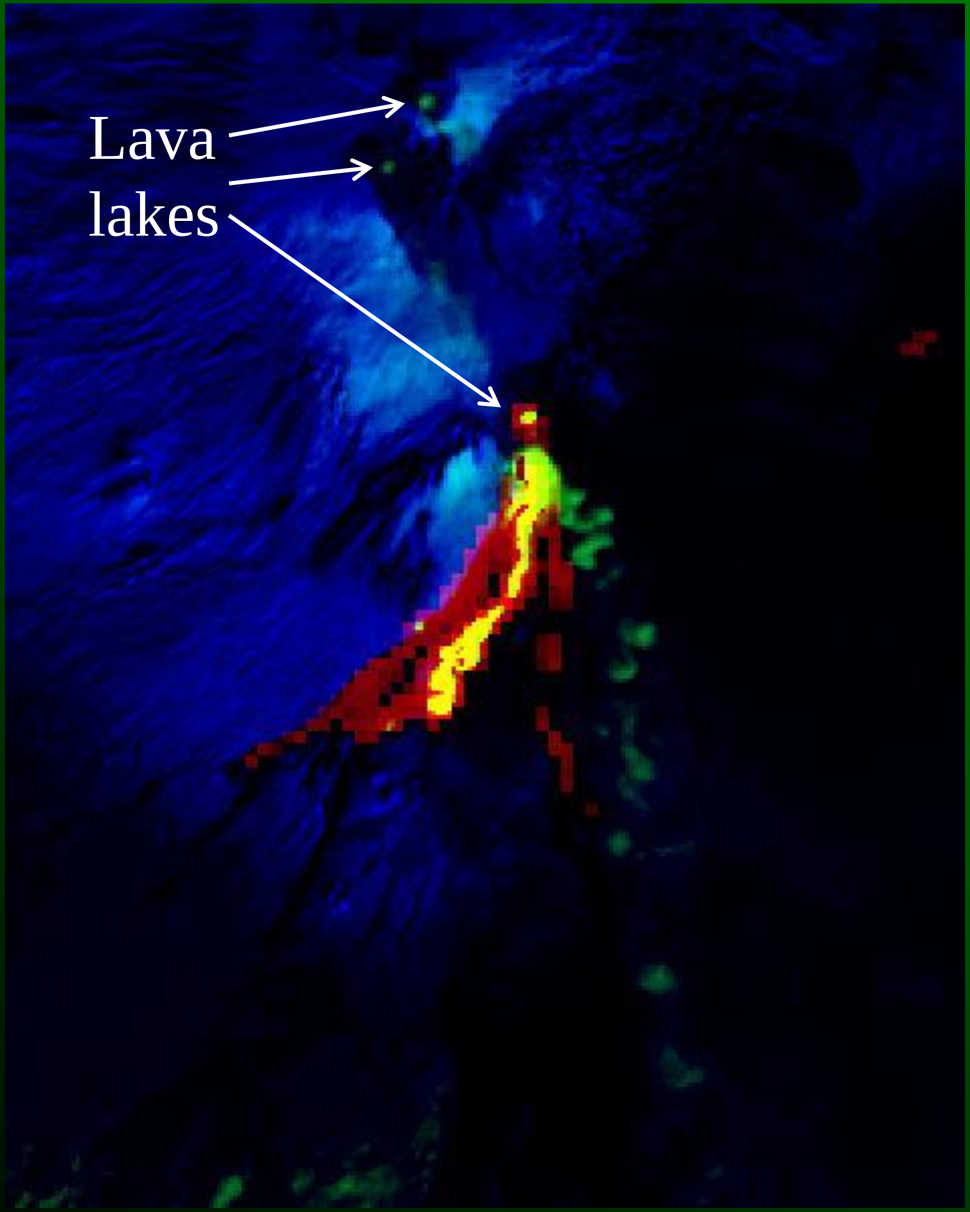
2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
7 May	29 July	5 June	15 Jan	7 Apr	26 Apr	3 Aug	19 Jun	21 Jun	7 Oct	26 May
		7 July	13 Mar	10 June		12 Aug	21 Jun	8 Aug		7 Aug
		23 July	19 July	26 June		7 Nov	14 Jul	21 Nov		
		3 Nov	11 Aug	6 Aug			21 Jul			
		30 Dec		13 Aug			30 Jul			
				22 Aug			2 Oct			

Multispectral TIR from Daytime ASTER (1 2 3)

VNIR image: plume is gray; flows are not incandescent

TIR image: plume composition is mostly ash; flows are obvious

Multispectral Daytime ASTER (2 3)



R=11um G=1.5um B=0.84um

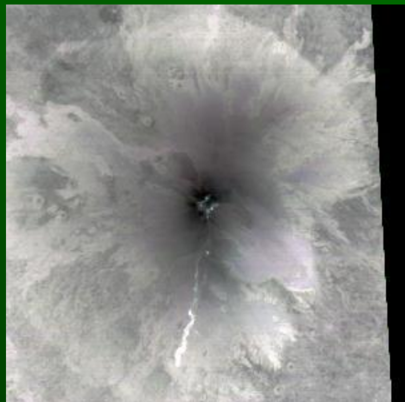
Lava flows vary in temperature; multispectral data allow better estimation of temperatures than TIR alone.

ASTER Nighttime TIR Scenes (1 2 3)

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6-Jun	9-Jan	19-Jan	7-Feb	13-Mar	5-Feb	29-Apr	15-Mar	21-Jun	6-Jan	2-Jan
22-Jun	25-Jun	22-Jan	20-Mar	15-Jun	4-Nov	31-May	18-May	11-Oct	15-Jun	3-Feb
8-Jul	11-Jul	28-Jan	14-May	26-Jun	11-Nov	2-Jul	19-Jun	5-Dec	24-Jun	1-May
24-Jul	15-Oct	4-Feb	17-Jul	3-Jul	27-Nov	25-Jul	26-Jun		10-Jul	10-May
10-Sep	24-Oct	12-Jan	26-Jul	14-Sep		3-Aug	12-Jul		2-Aug	
28-Oct		11-May	18-Aug			10-Aug	12-Dec		15-Nov	
		20-May				4-Sep				
		28-Jun				13-Oct				
		23-Jul				7-Nov				
		16-Sep								
		18-Oct								
		27-Oct								
		19-Nov								
		28-Nov								

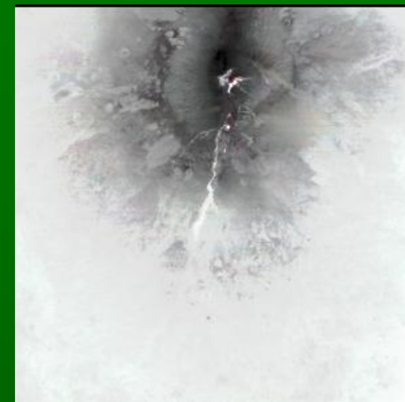
Selected 2002 ASTER Night TIR (1 2 3)

January 19

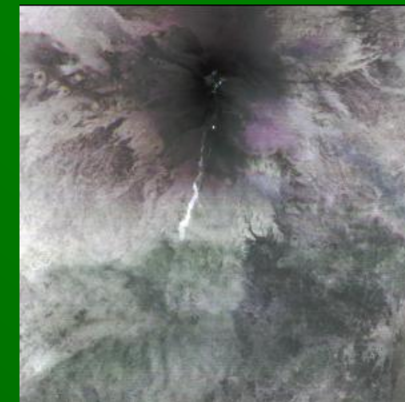


January 28

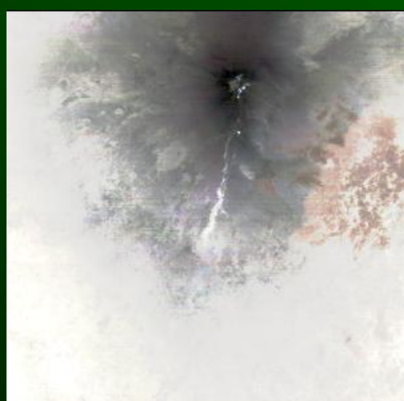
May 11



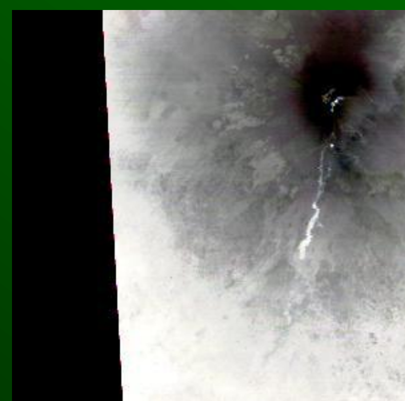
May 20



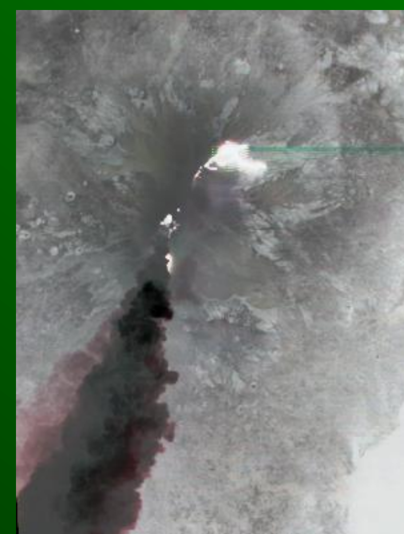
June 28



July 23



October 27

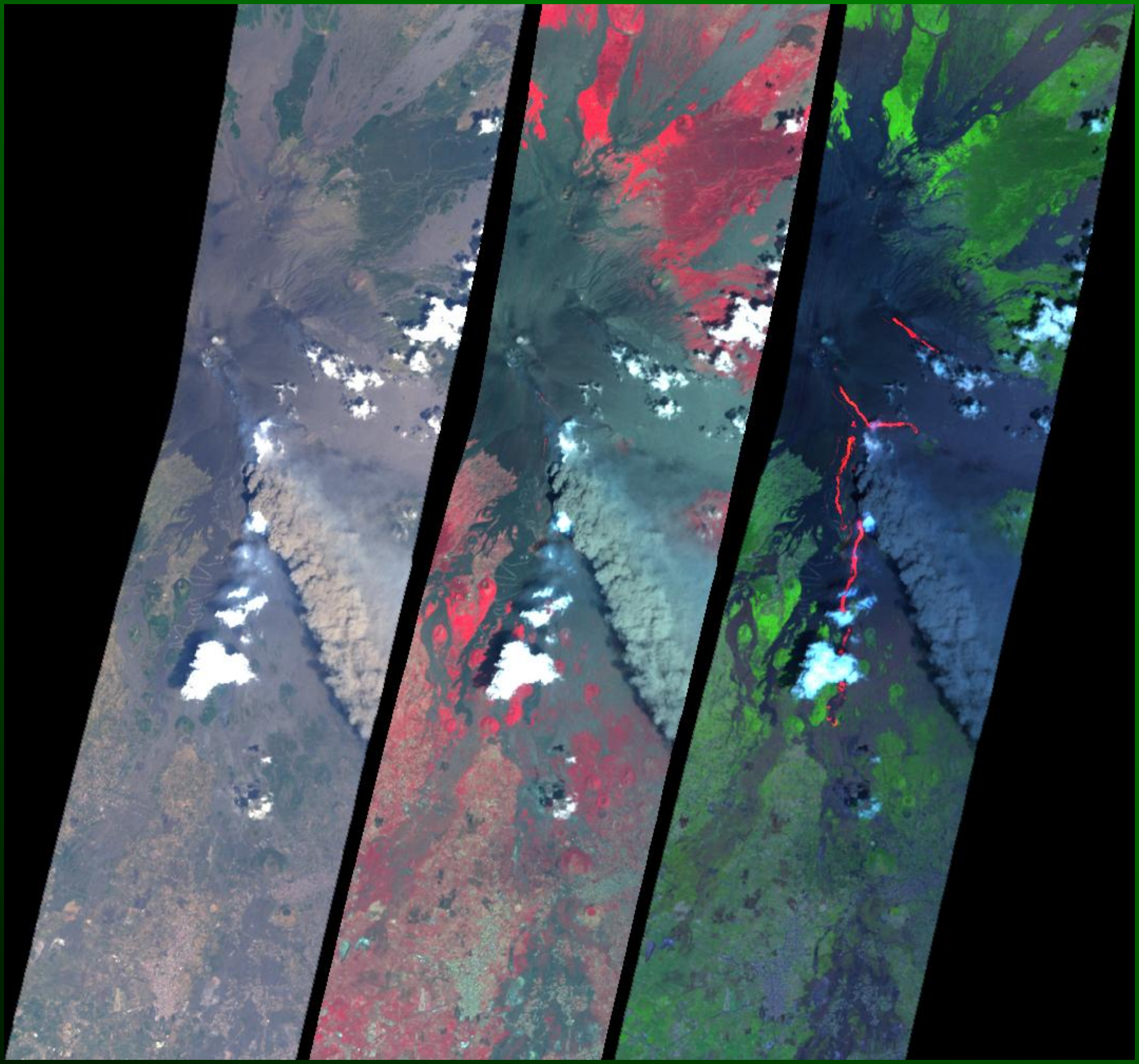


EO-1 Hyperion Daytime Scenes (2 3)

EO1H1880342009281110pf_sgs_01
EO1H1880342008206110kf_sgs_01
EO1H1880342008152110kf_sgs_01
EO1H18803420071901110kf_sgs_01
EO1H1880342007134110kf_sgs_01
EO1H1880342006303110pf_sgs_01
EO1H1880342006298110pf_sgs_01
EO1H1880342005316110kf_sgs
EO1H1880342005302110kf_sgs
EO1H1880342005205110pf_hgs
EO1H1880342004283110pw_sgs
EO1H1880342004260110kw_pf1
EO1H1880342003223110kf_sgs
EO1H1880342003207110kx_hgs
EO1H1880342003177110ky_sgs
EO1H1880342001267110kp_sgs
EO1H1880342001242110po_sgs
EO1H1880342001203110kp_sgs
EO1H1880342001194110po_sgs

July 22, 2001 Hyperion Etna Data (2 3)

0.65-0.55-0.44 0.87-0.65-0.55 1.65-0.87-0.65

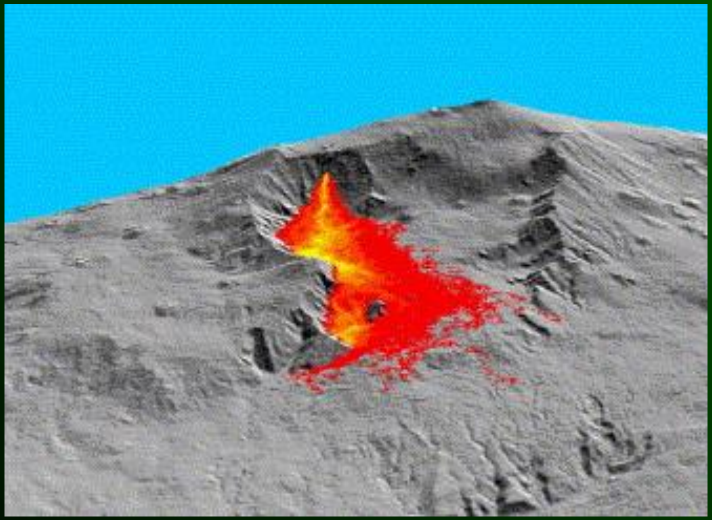


SO_2 Determination with ASTER TIR(1)**

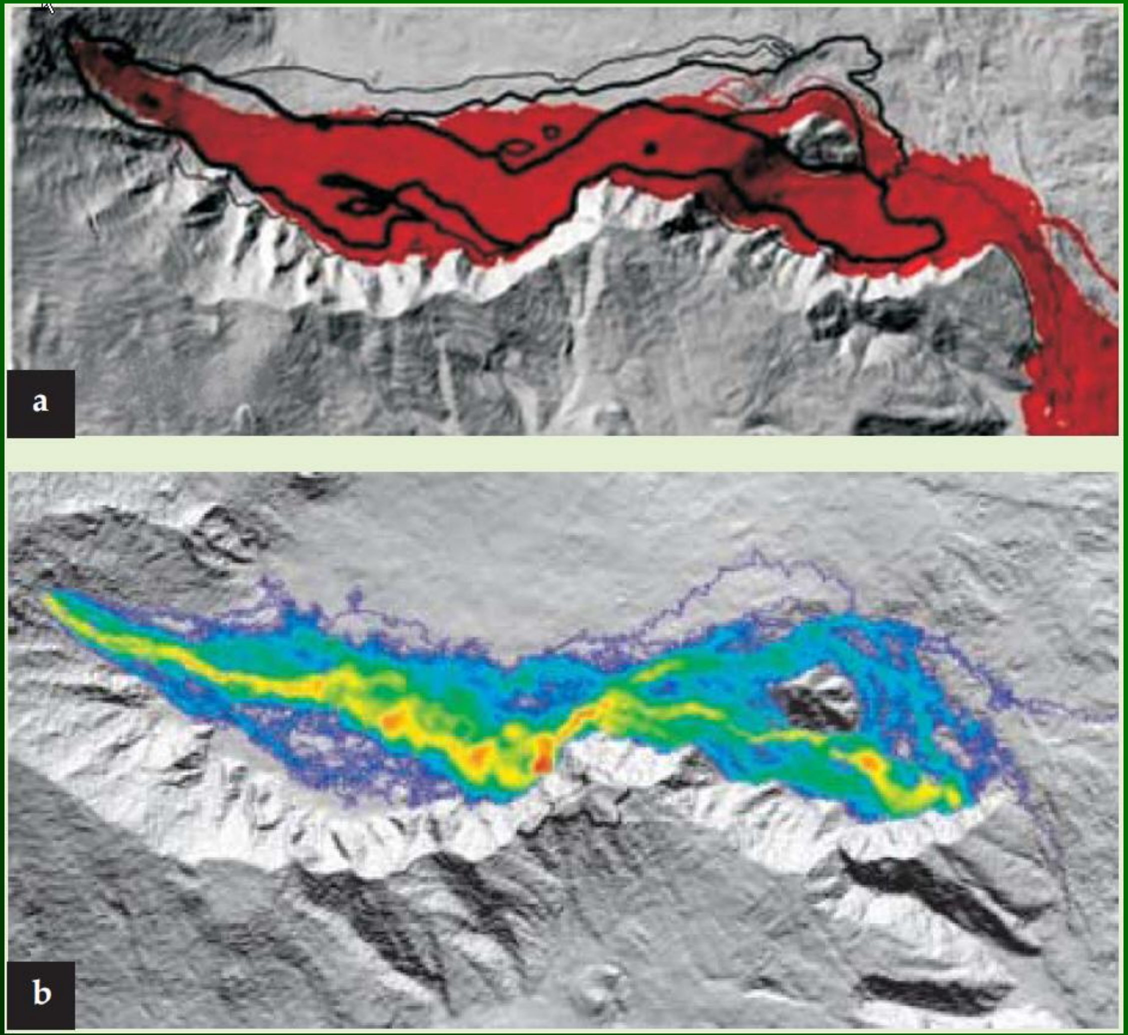
Will be discussed
in following talk
by Vince Realmuto

Lava Flows, Energy Radiated, Extent (2)

Lava flow models require DEM data, effusion rates, and Temperature distributions



Damiani et al., 2006

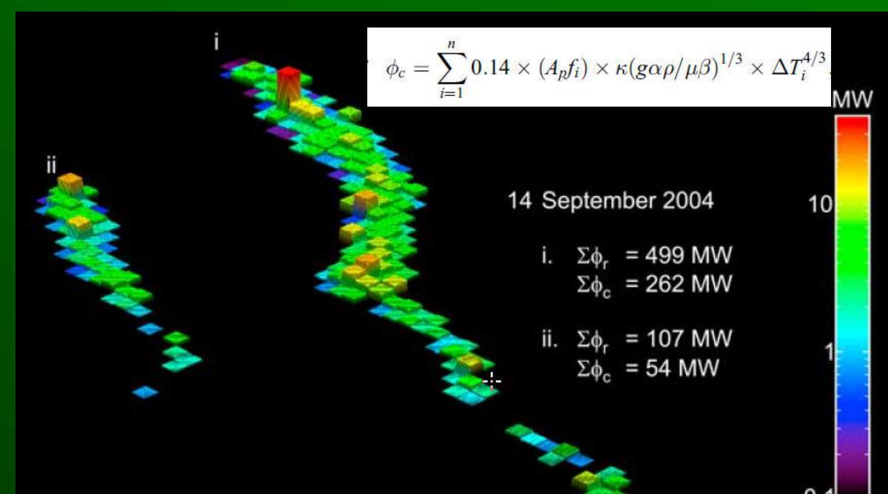


Wright et al., 2008

Lava Flows, Energy Fluxes (2)

Sept 14, 2004 nighttime combined ASTER + EO-1 Hyperion data for lava flows; most TIR pixels are saturated.

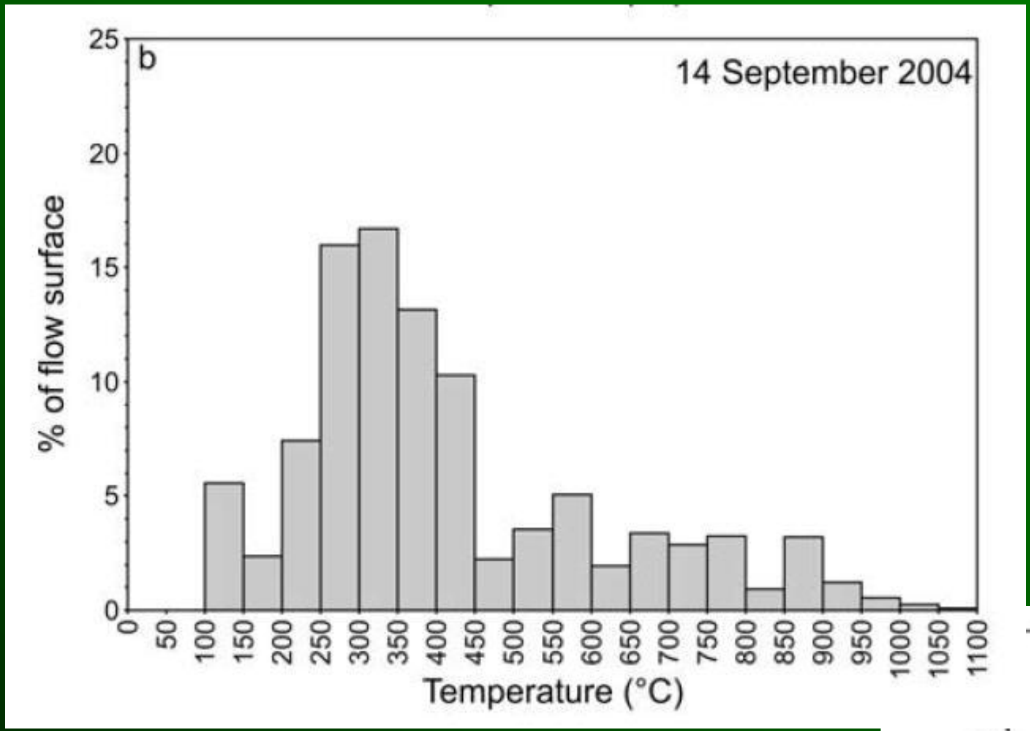
EO-1 Hyperion data



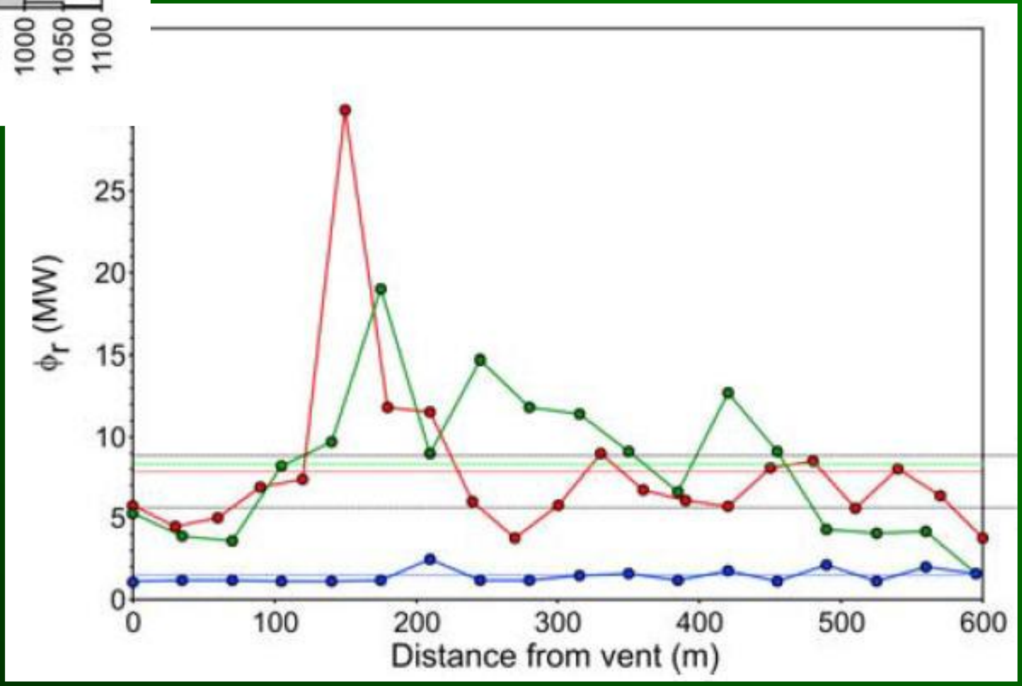
Radiant heat flux from Hyperion

Wright et al., 2010, JGR

Lava Flows, Energy Fluxes (2)



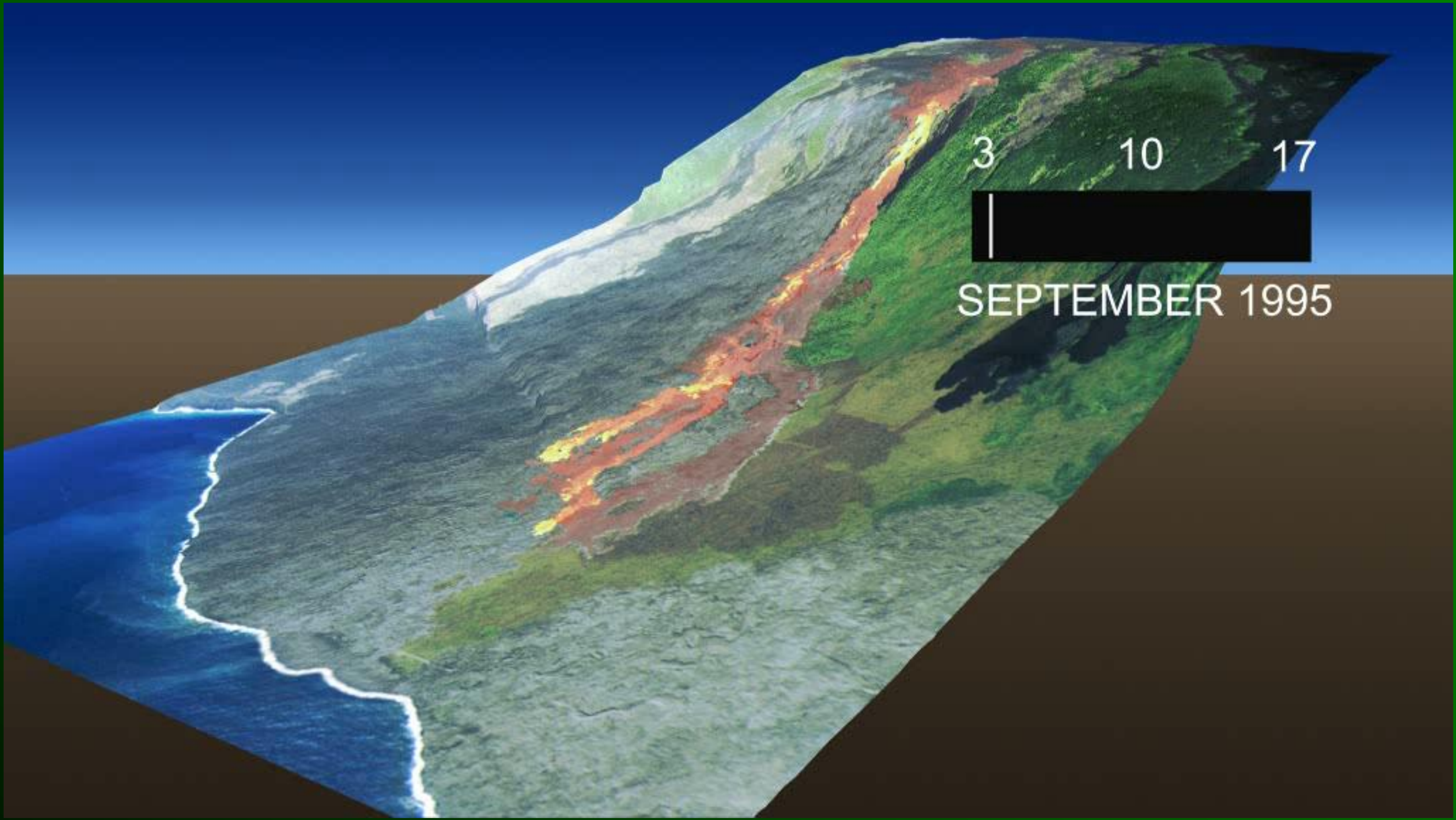
Temperature histogram for flow unit I from Hyperion data



Radiant heat flux as a function of distance from the vent. September 14 is red curve.

Wright et al., 2010, JGR

Lava Flow Dynamics (2)

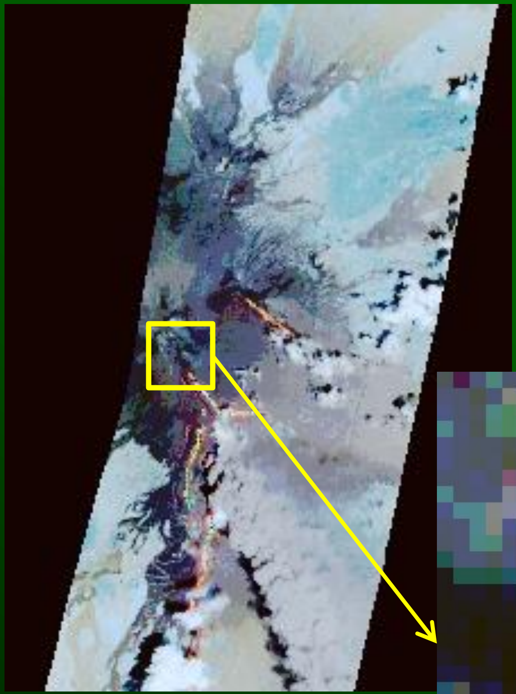


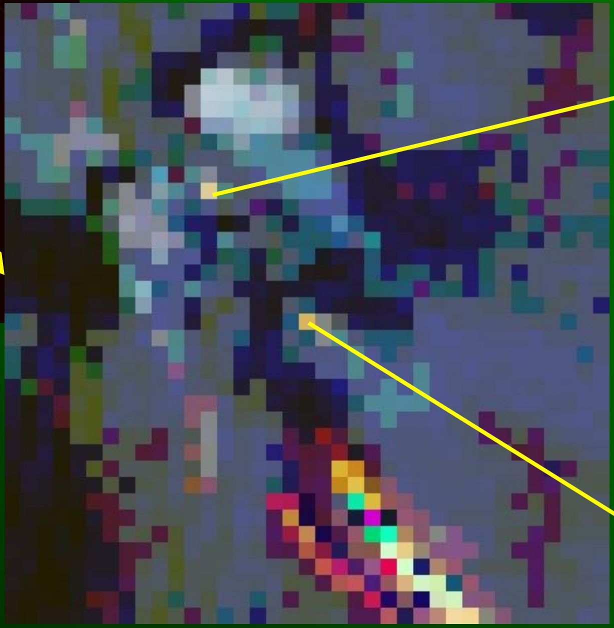
Courtesy of Vince Realmuto

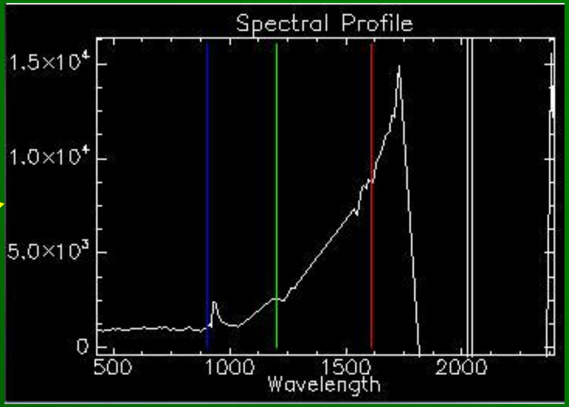
ETNA Craters

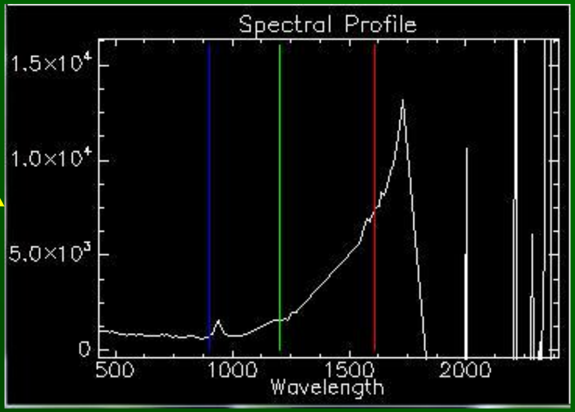
Craters, Energy Fluxes (3)**

July 22, 2001 EO-1 daytime image of craters and flows. Radiance of incandescent craters fills one pixel; 60m size allows only pixel integrated temperature to be estimated.



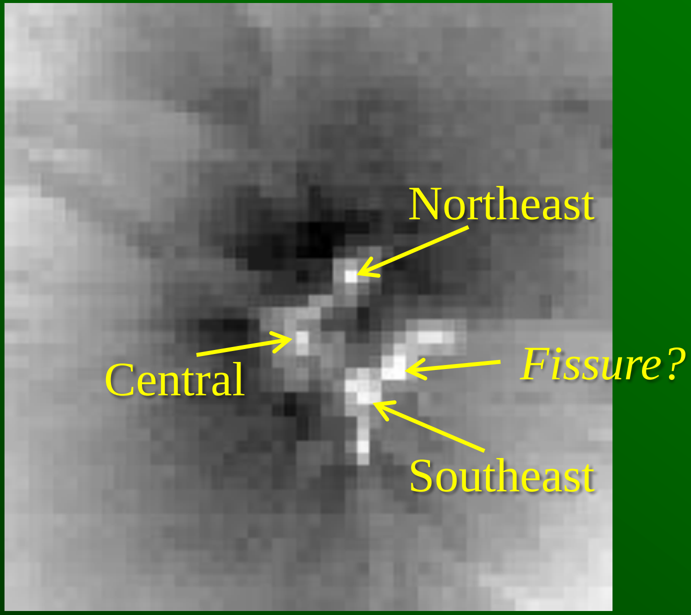




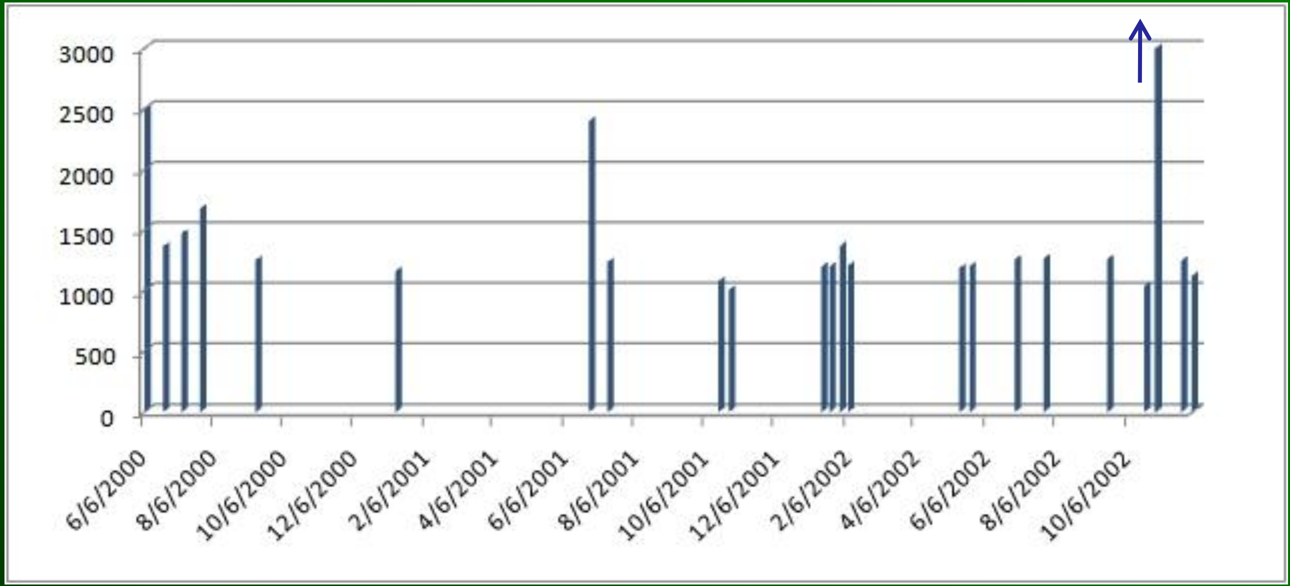


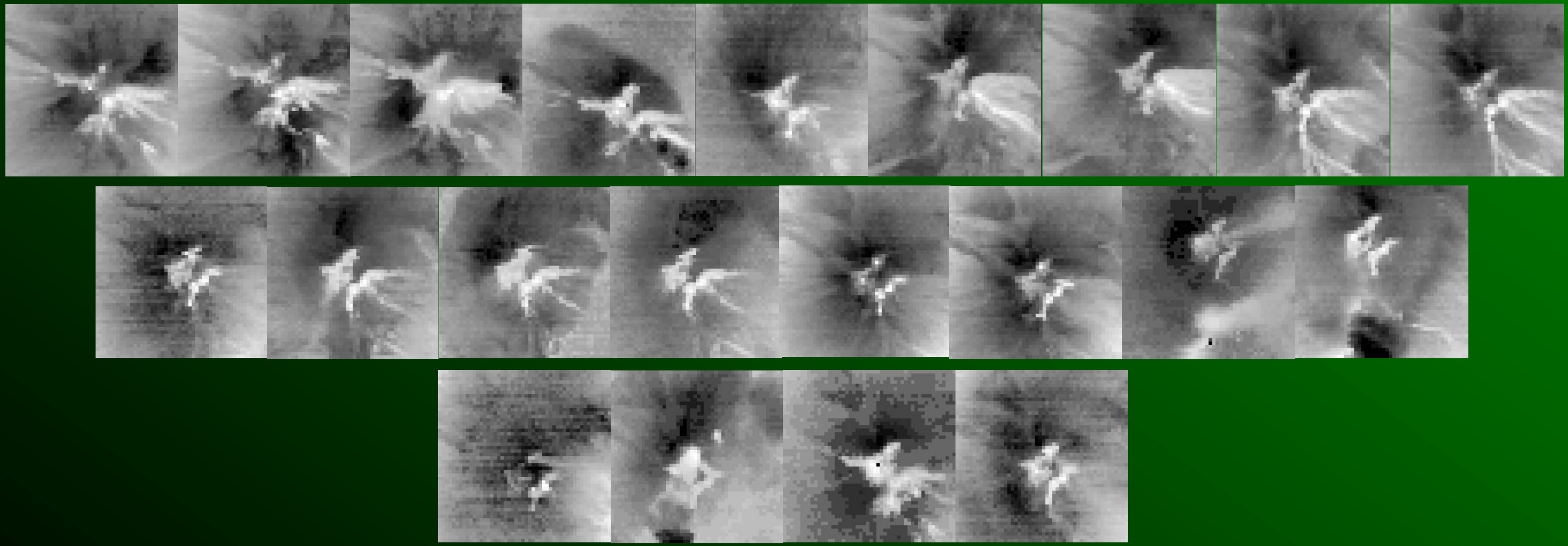
Craters, Energy Fluxes (3)**

❖ Between 2000 and 2010, 61 ASTER cloud-free nighttime TIR scenes were acquired (~6/yr, or one scene every 2 months)
❖ Summit area was extracted, and maximum radiance of craters was determined.
❖ *Still to do: compute total flux from craters*

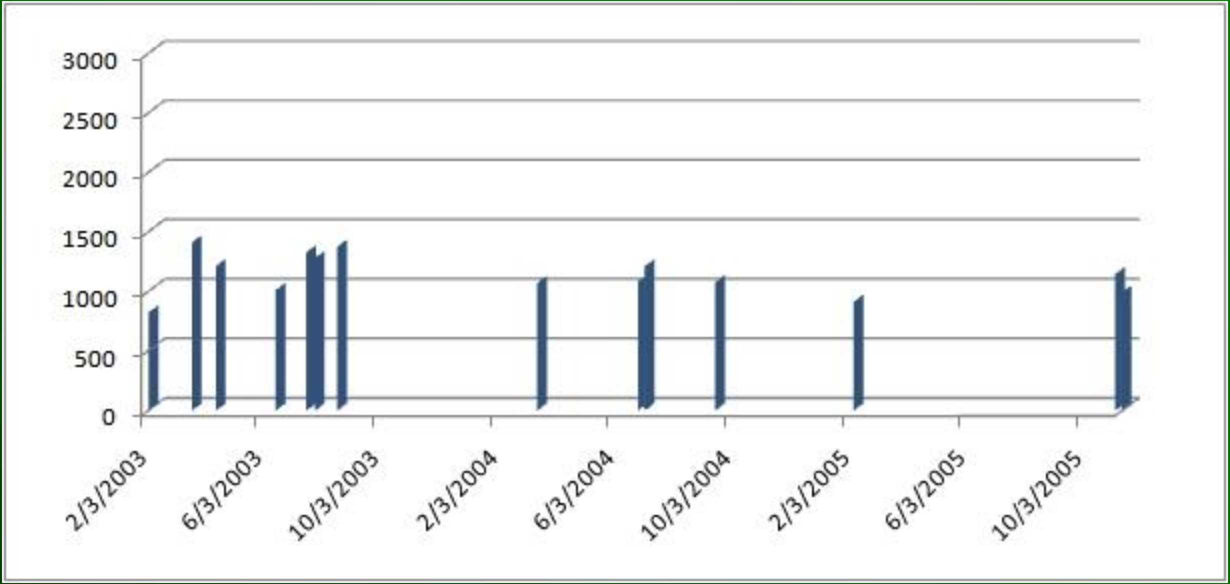


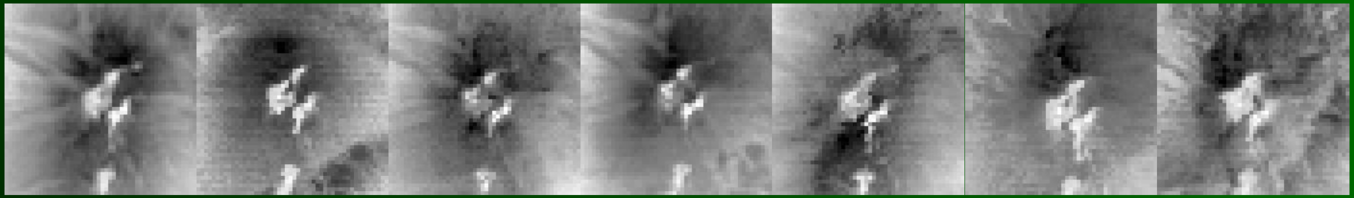
Craters, Energy Fluxes (3)** 2000-2002



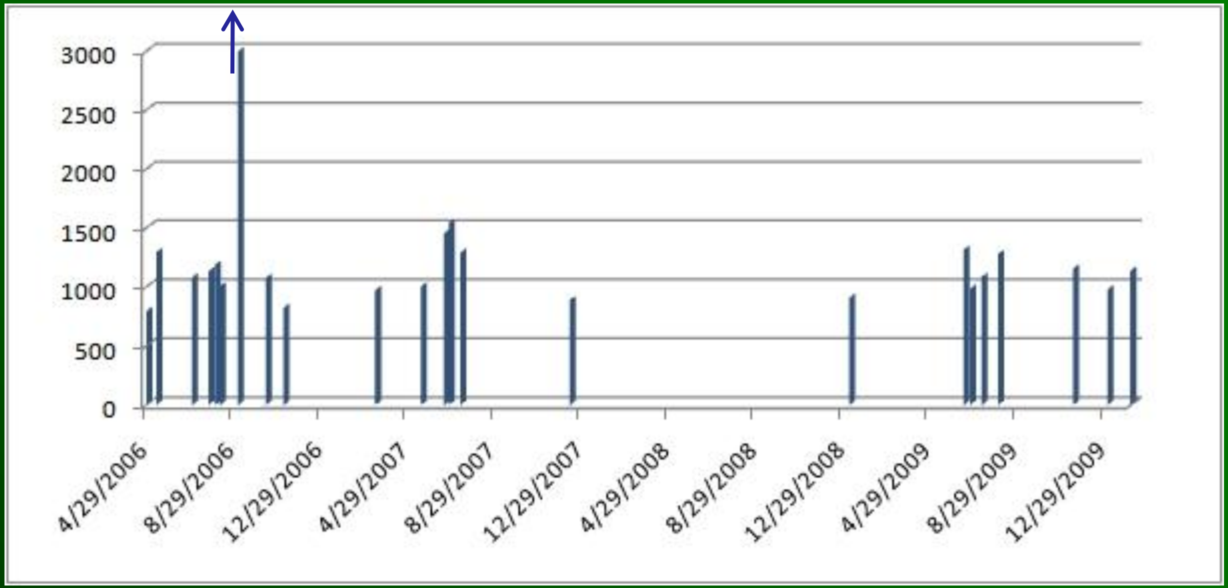


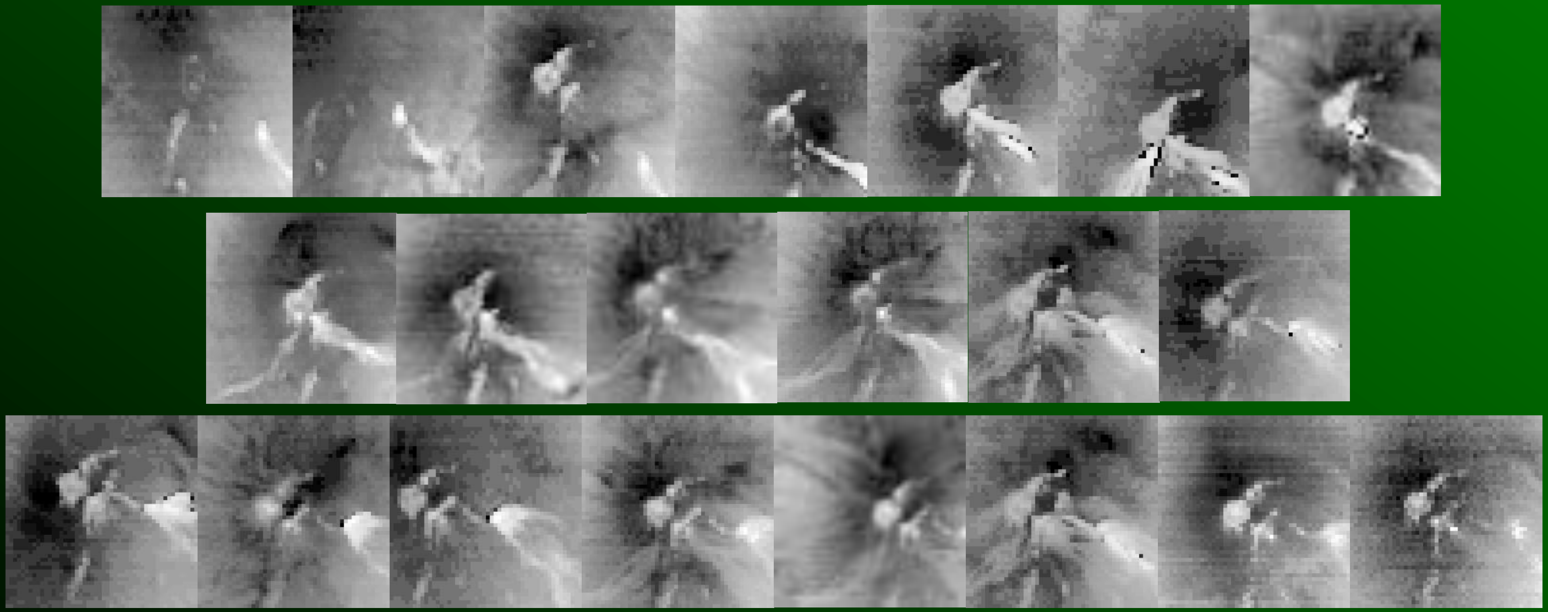
Craters, Energy Fluxes (3)** 2003-2005





Craters, Energy Fluxes (3)** 2006-2010





Simulated HyspIRI Data Sets

- ❖ 5 daytime dates and 1 nighttime date were selected that were cloud-free, and had simultaneous Hyperion and ASTER acquisitions

- ❖ Hyperion data were re-sampled to 60m, duplicate channels removed, data scaled to radiance-at-sensor

- ❖ ASTER TIR bands were re-sampled to 60m, registered to Hyperion, data scaled to radiance-at-sensor

- ❖ 226-band images created with ENVI header files

Simulated HyspIRI Daytime Data Sets

Cloud-free Hyperion and ASTER Data

Hyperion	ASTER
2001-7-13	2001-7-29
2001-7-22	
2001-8-5	
2001-8-14	2002-6-5
2001-8-30	2002-7-7
2001-9-24	2002-7-23
	2002-11-3
2002-11-12	2002-12-30
2003-1-15	2003-1-15
2003-3-20	2003-3-13
2003-6-26	2003-7-19
2003-7-19	2003-8-11
2003-7-26	2003-1-15
2003-8-11	
2004-9-16	2004-6-26
2004-10-9	2004-8-6
	2004-8-22

Hyperion	ASTER
2005-3-16	2005-4-26
2005-3-18	
2005-7-24	2006-8-3
2005-10-29	2006-8-12
2005-11-5	2006-11-17
2005-11-12	2006-11-30
2005-11-30	
	2007-6-19
2006-10-25	2007-6-21
2006-11-24	2007-7-14
2006-11-29	2007-7-21
	2007-7-30
2007-5-14	2007-10-2
2007-7-9	
	2008-6-21
2008-5-31	2008-8-8
2009-10-8	2009-5-23
	2009-10-8
	2010-5-10
2011-6-30	2011-2-6
	2011-4-4
	2011-6-30

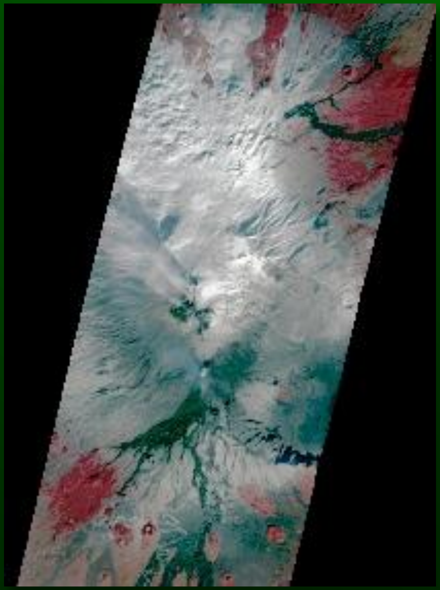
Simulated HyspIRI Daytime Data Sets
January 15, 2003

- On 15 January 2003, ash emission increased at the 2,750-m-elevation pyroclastic cone on the volcano's upper S flank. There was also an associated increase in lava emission towards the south
- The volcano was snow covered down to the 1500m level

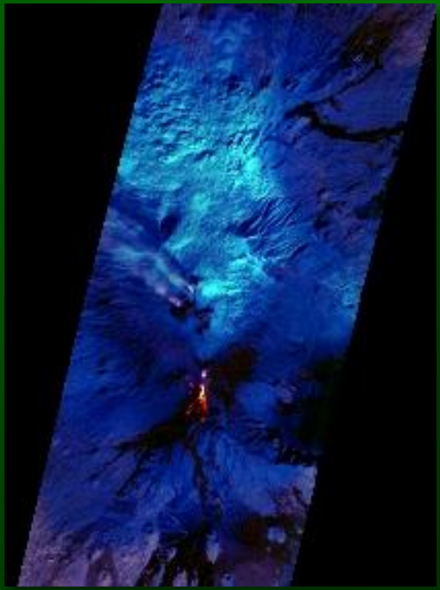
- Smithsonian/USGS Weekly Volcanic Activity Report

Simulated HyspIRI Data Sets
January 15, 2003

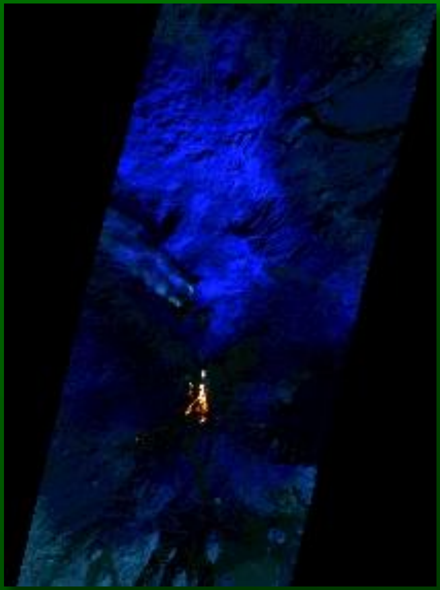
.91, .65, .55



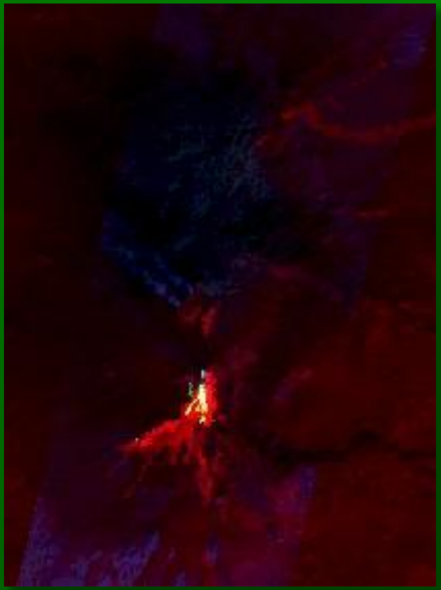
1.2, .91, .65

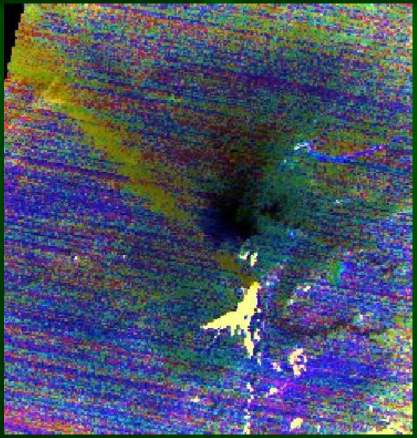


1.6, 1.2, .91



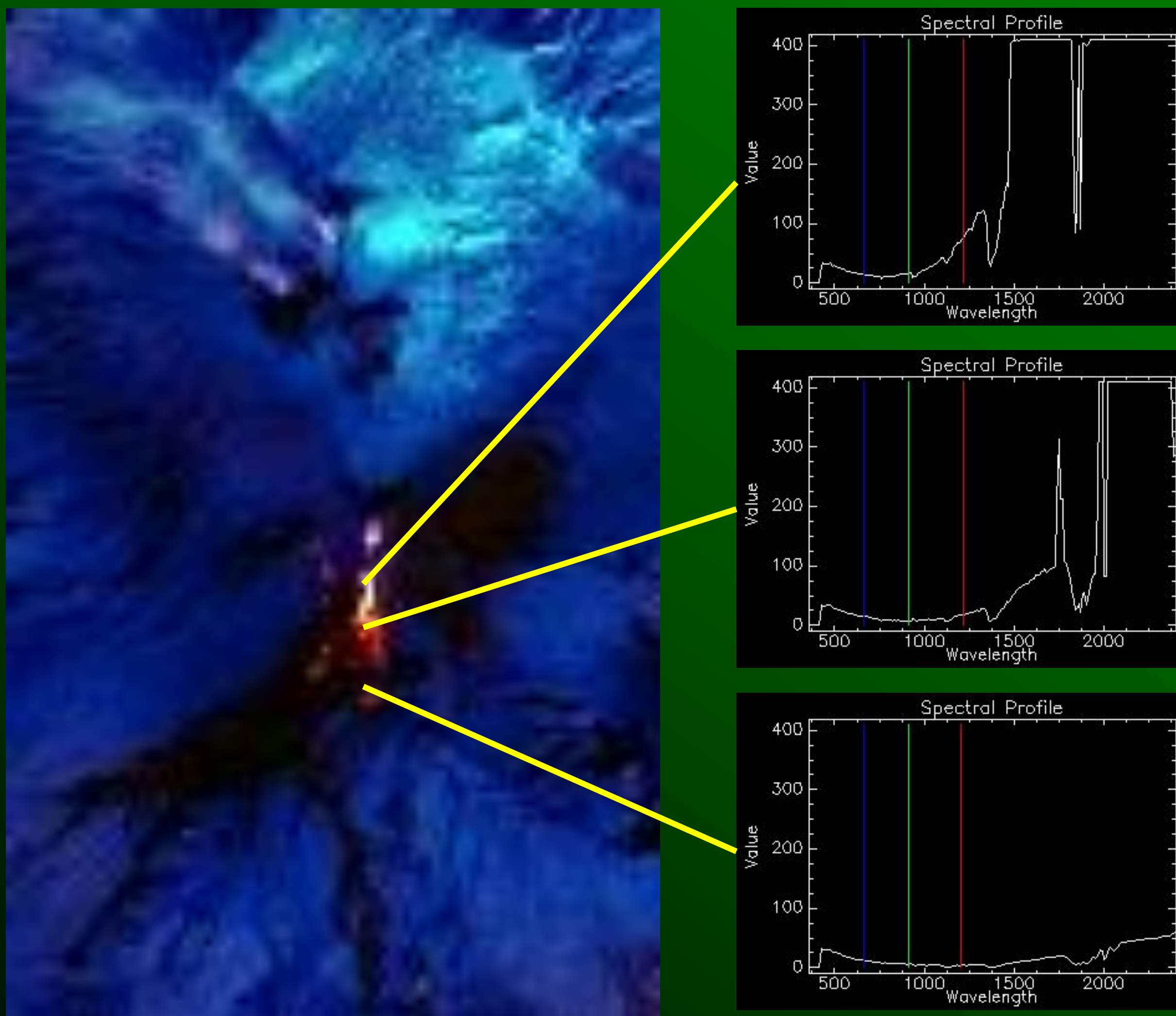
9.0, 1.6, 1.2





11.3, 10.6, .8.6

Simulated HyspIRI Data Sets**
January 15, 2003

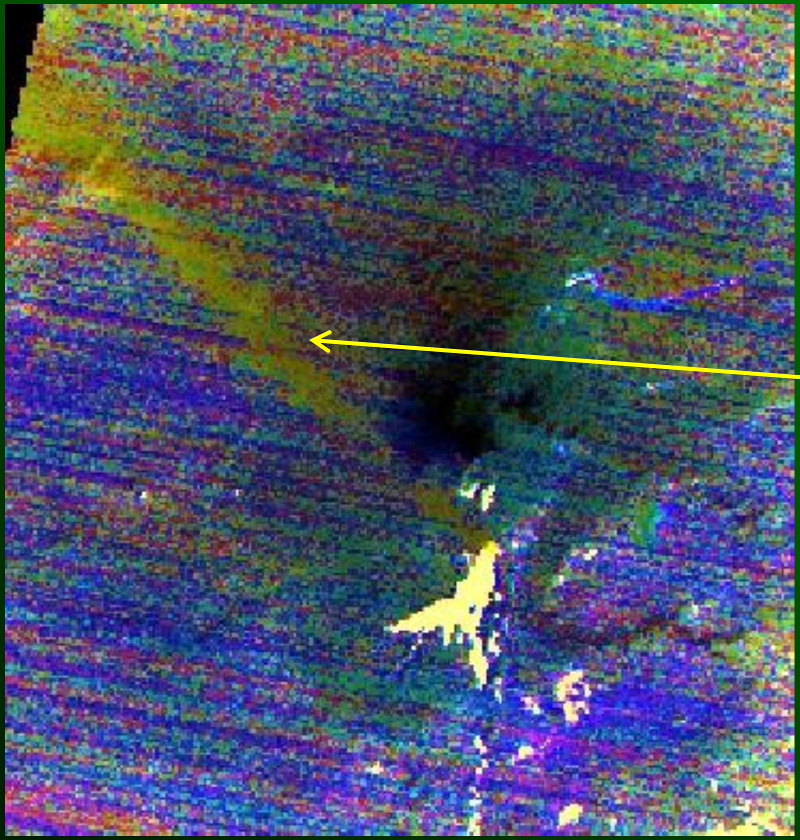


Hottest, “saturated” lava

Hot lava

“Warm” lava

Simulated HyspIRI Data Sets
January 15, 2003

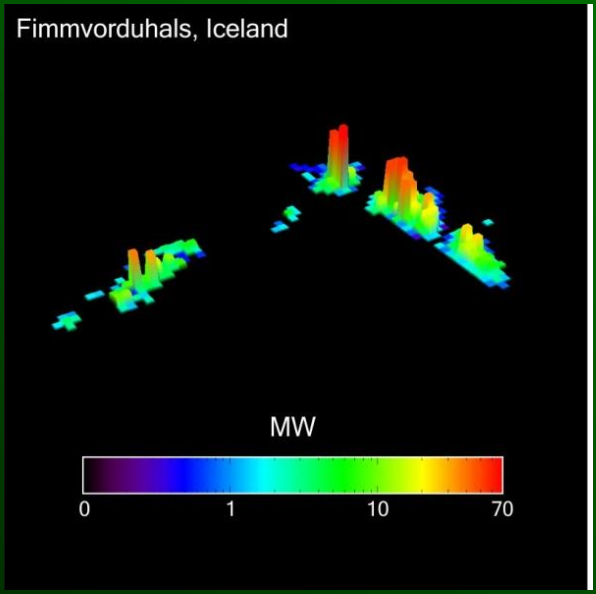


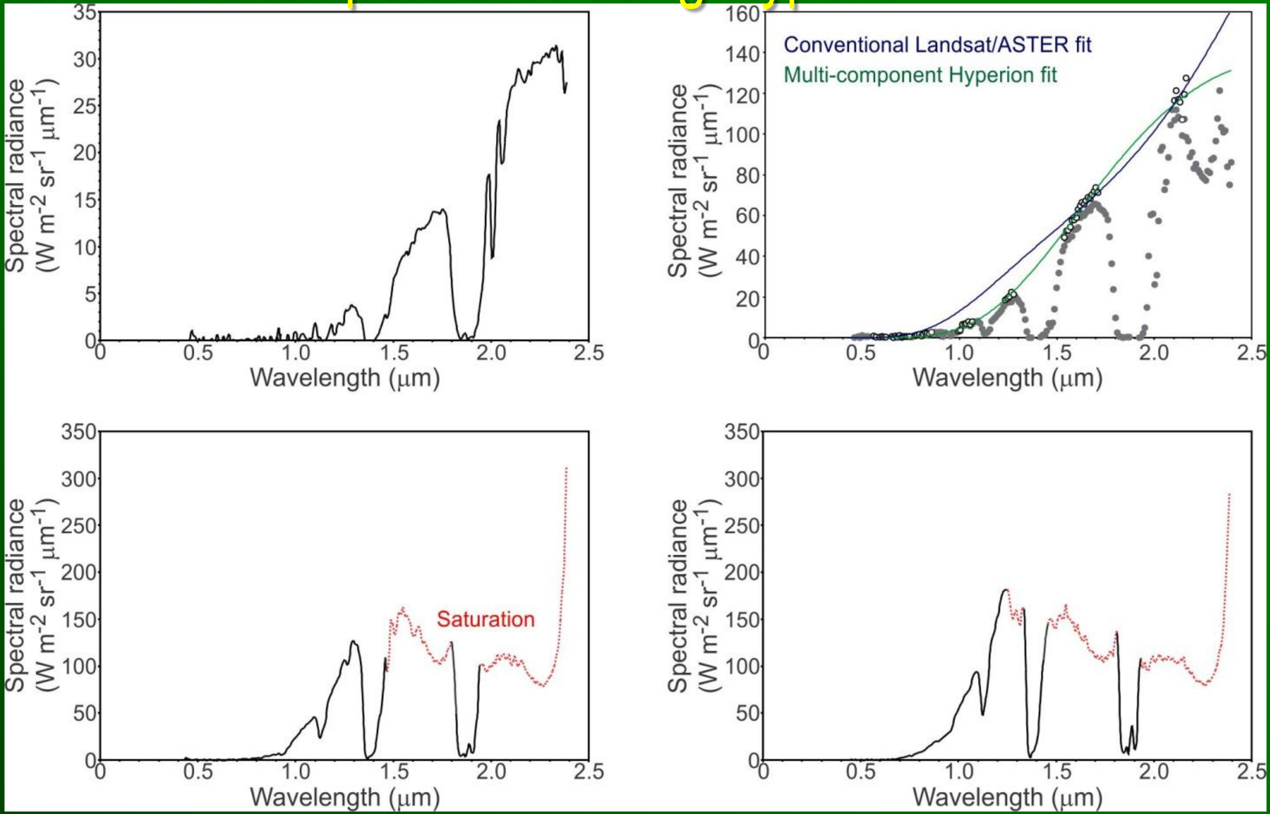
11.3, 10.6, .8.6

Yellow color of plume in this d-stretch image indicates that the dominant components are SO_2 and ash

4 micron Channel Saturation

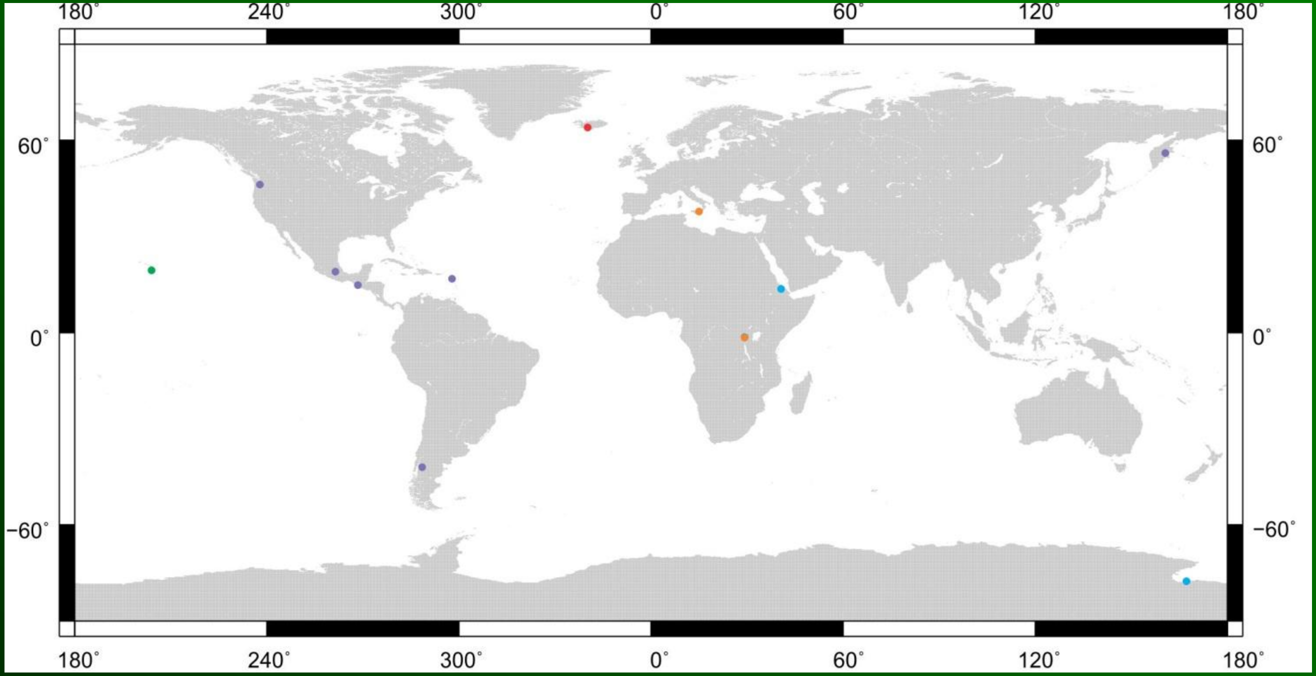
Retrieving lava surface temperatures using Hyperion





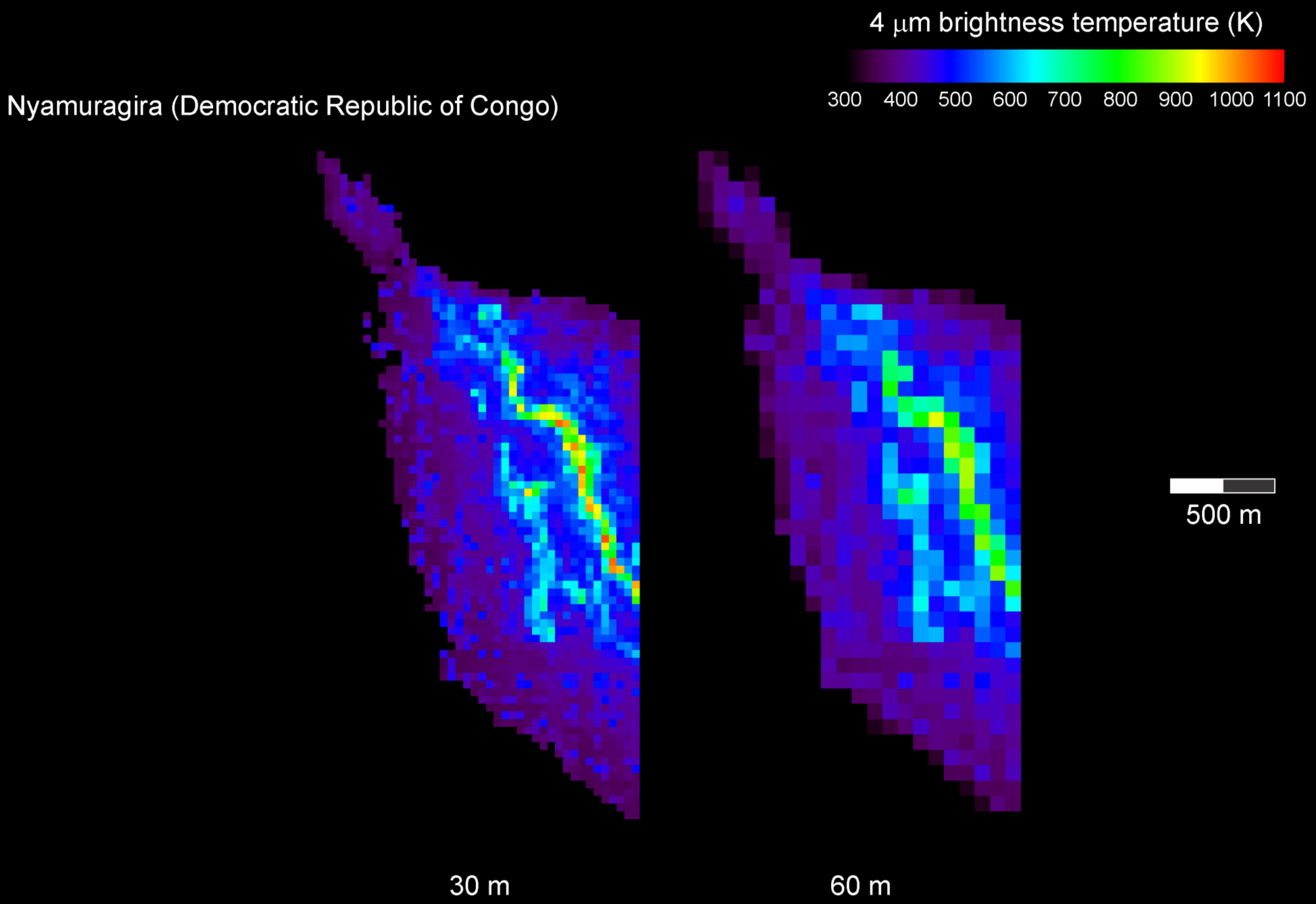
- Used Hyperion images (nighttime data) to calculate the sub-pixel temperature distributions of active lavas as a first step to retrieving surface leaving radiance at 4 μm at 30 m scale.
- Unsaturated data are always available from an imaging spectrometer, so Hyperion resolves the temperatures of even the hottest lava flows

How hot are Earth's lava flows, domes and lakes?

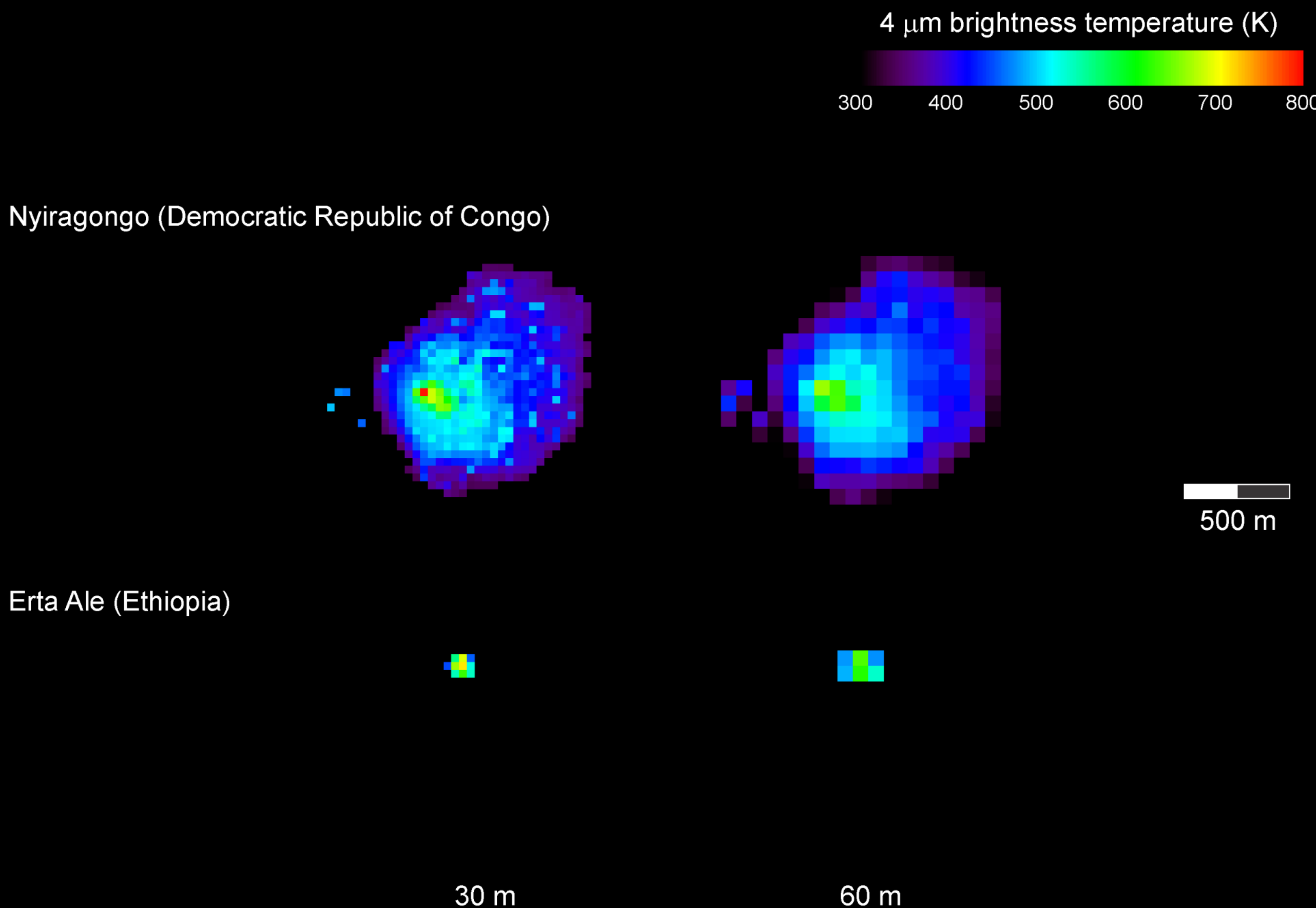


10 images of ʻaʻā lava flows
10 images of pāhoehoe lava flows
20 images of domes
20 images of lakes
1 image of fountains

- Analyzed Hyperion images acquired at 16 different volcanoes, exhibiting the full range of common eruption styles to ensure the results were representative

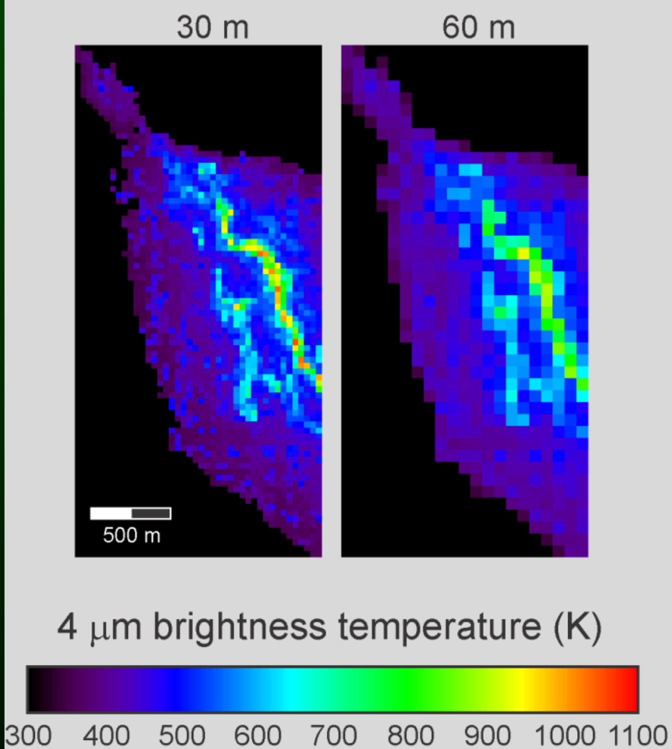


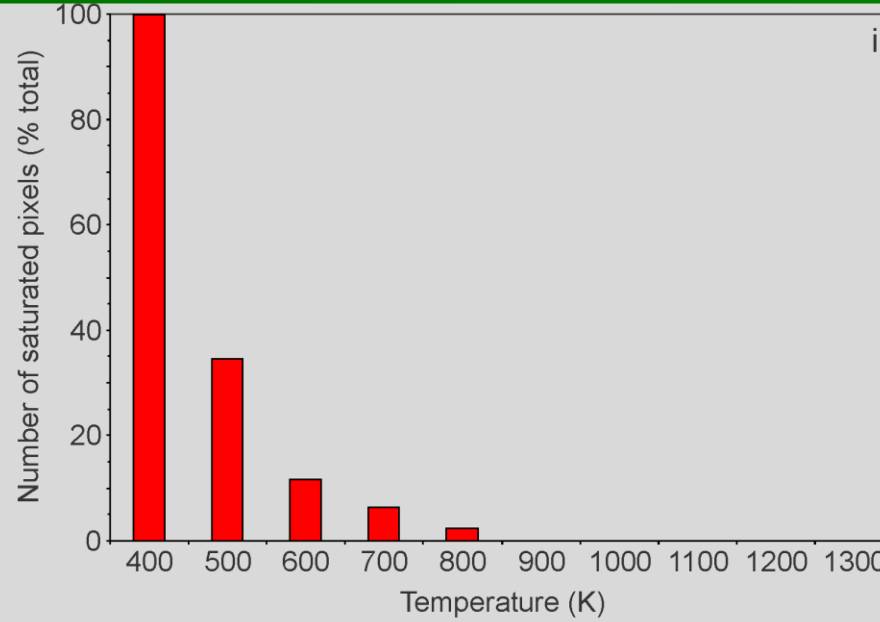
Nyamuragira (Democratic Republic of Congo)
4 μm brightness temperature (K)
300 400 500 600 700 800 900 1000 1100
500 m
30 m
60 m

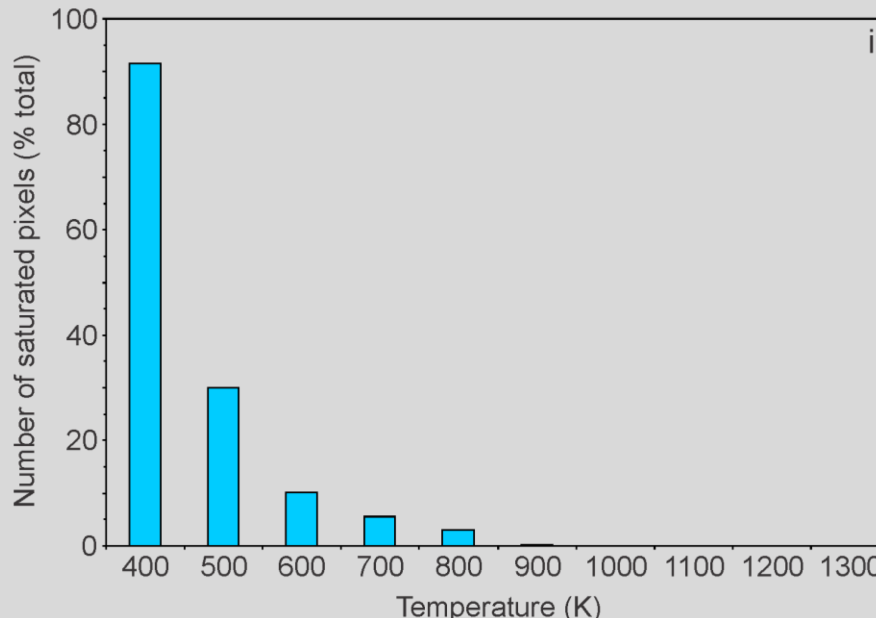

4 μm brightness temperature (K)
300
400
500
600
700
800
Nyiragongo (Democratic Republic of Congo)
500 m
Erta Ale (Ethiopia)
30 m
60 m

Calculated incidence of HyspIRI 4 μm channel saturation as a function of L/T_{sat}

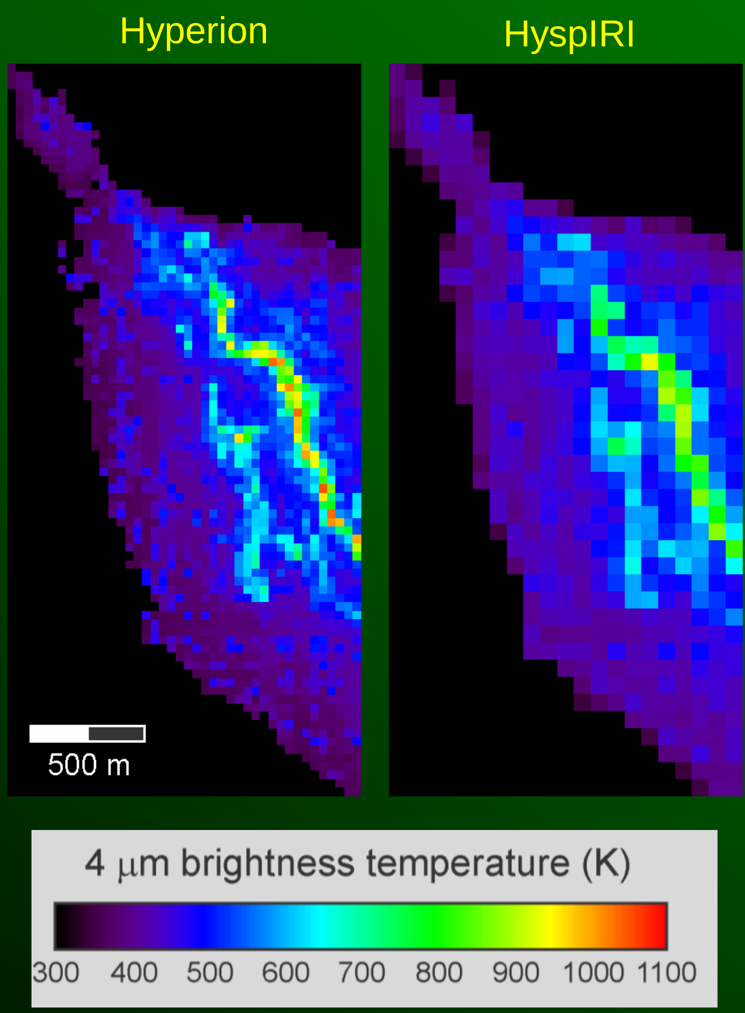
T_{sat}(K)	$\#_{sat}$(i)	$\#_{sat}$(ii)
400	471	432
500	163	142
600	55	48
700	30	26
800	11	14
900	0	1
1000	0	0





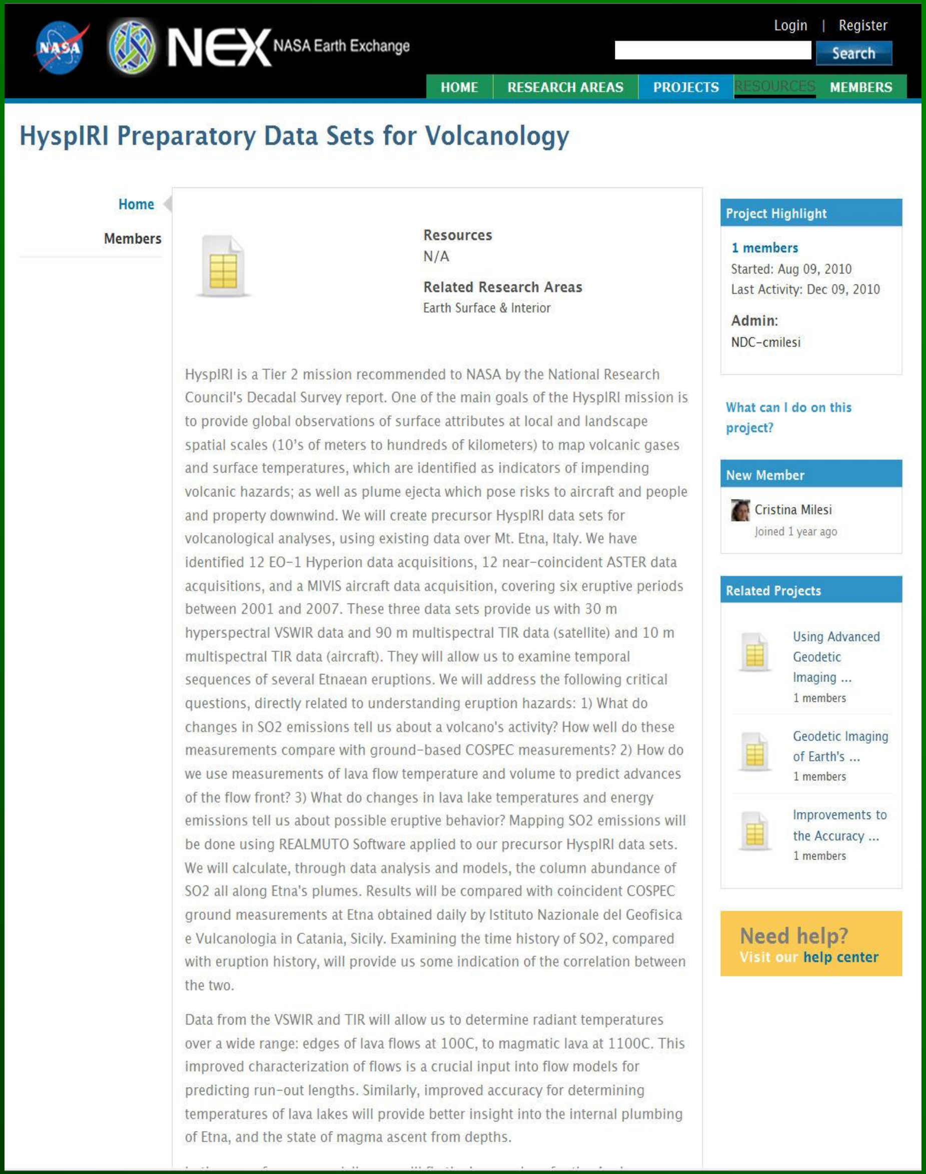


Conclusion: set 4 μm T_{sat} no less than 1100 K



- Aggregation of four most radiant pixels at HyspIRI resolution yields a $T_{4\mu m}$ of 1041 K

HyspIRI Volcanology Project Outreach



http://HyspIRI-Volcanology.jpl.nasa.gov

https://c3.nasa.gov/nex/

CONCLUSIONS

- T_{sat} 4μm channel >1100K

- Short repeat time mandatory for volcano monitoring: Hyperion and ASTER do not provide sufficient frequency at 10-16 days, given cloud cover. HyspIRI repeat of 5 days (daytime) PLUS nighttime acquisitions will be stunning for volcanology.

- Lava flow energy fluxes with topo and flow models can be used to estimate flow duration and extent. Requires very frequent flow observations (~several days) to measure dynamics.

- Crater activity (T, energy flux) monitoring requires very frequent observations to investigate correlation with eruption potential; insufficient at present.